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In the second year of the grant I continued three projects initiated in the first year, and began two new lines of research. A study of contingent coding in normality judgments yielded disappointing results. We started a systematic exploration of the relation between discriminability and similarity, which we plan to extend to categorization and normality. A series of studies established essentially perfect dimensional independence in object-specific priming. We conducted a theoretical and empirical examination of close counterfactuals. Two separate projects dealt with the process of comparison, continuing and extending work reported last year.

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NORMS AND PERCEPTION OF EVENTS

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Prepared for
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Summary

A study of normality failed to confirm our hypotheses about the role of individuating features in contingent coding. From an attempt to control effects of similarity in the normality paradigm we were led to search for ordinal discrepancies between the similarity and discriminability of stimulus pairs, and confirmed that effect. A set of studies of object-specific priming established that priming of a discrimination on one dimension is almost perfectly independent of irrelevant variation on other dimensions. A theoretical and empirical study of conditions in which people say that 'X almost happened' related the intuitive notions of causality and probability to a hybrid variable of propensity. A study of the assignment of the roles of topic and referent in same/different judgments was completed. A collaborative study with Jim Sherman explored possible relations between processes of comparison and choice, with very promising results. A paper on counterfactuals is in press, and a paper on comparison is almost ready for submission.

Administration and personnel

Since July 1989, the following people have been partly supported by the grant (in addition to my own summer support): Amy Hayes (technical assistant); Ephram Cohen (part-time programmer); Suzanne O'Curry, Maria Stone, and Carol Varey (graduate students).

Research completed and in progress

The work carried out since the last report (end of July, 1989) falls into five separate projects, which are described in the following sections.

Section 1: Normality and Individuation
Varey and Kahneman

One of the most interesting questions arising from our earlier series of experiments on normality judgments concerns the conditions under which contingent coding will be observed. When are some attributes of a stimulus entirely subordinated to another attribute or correlated cluster of attributes? In the preceding annual report we reported that dominance patterns were quite common in the data, but that contingent coding was quite difficult to obtain. In fall 1989, a series of nine further experimental conditions was investigated to shed light on this issue.

Before discussing the results of this study, the experimental method will be reviewed briefly. Up to four subjects are run in a group. Typically, four to six groups are run on each experimental condition. A session lasts approximately 45 minutes, during which time subjects participate in eight to ten short experiments. Each experiment takes approximately 4 minutes for the subjects to complete. A series of 8 presentations of events on a computer monitor acquaints the subjects with the two norms for the experiment. Norms are defined on three attributes or three sets of conjoined attributes. Following this, trials are presented in 12 blocks of nine events: eight norm trials in random order followed by a test pattern or event. The test event combines attributes of both norm patterns, and is accompanied by a probe asking subjects to respond 'yes' or 'no' to a question about whether a particular attribute is normal. In each test trial, the queried attribute is normally accompanied by one of the other attributes present in the display and is not normally accompanied by the other attribute.

Most of our previous experiments included position as an attribute. Contingent coding under these conditions obtains when two conditions are satisfied: (1) one attribute, A, dominates the other, B; this is shown when a high percentage of subjects answer questions about position (abbreviated hereafter as P?) by saying that it is normal if A is normal, and abnormal if A is abnormal; (2) B is judged to be normal if it is paired with the normal value on A, despite being in the wrong position.

Previous results indicated that this second condition was obtained in many cases when A represented a cluster of static properties of an object and B represented a cluster of motion properties of an object. There seemed to be some indication from the results that clusters of attributes were necessary to obtain contingent coding for objects in motion, and possibly even to obtain dominance. Contingent coding appeared to be enhanced when the object was referred to as an object rather than as a shape or as a color. Another case satisfying contingent coding was faces (A) with emotional expressions (B).

To account for these results we hypothesized that contingent coding is most likely to occur for objects that are highly individuated. If an object seems to come from a large population of possible objects (in the Garnerian sense of an object having many alternatives) then all of its dimensions will be relevant to its identity. Under such circumstances, a relocation of the object will carry its attributes with it. Thus static and motion properties will all be subordinated to object identity.

The present series of experiments was intended to investigate the factors involved in dominance and in contingent coding, and at the same time to examine an alternative interpretation of our other results, which would explain judgments of normality in terms of discriminability or similarity.

Normality and discriminability

Four conditions in the present series were an attempt to address directly the relationship between discriminability and normality. All these conditions used position as the third attribute. In conditions 1 and 2 the displays were static: attribute A was shape and B was size. In conditions 3 and 4 the displays were moving objects: attribute A was shape and B was direction of motion. In conditions 1 and 3 the two norm shapes were distinctly different and color was held constant across the two norms. In conditions 2 and 4 the two norm shapes were very similar and the colors differed but were similar. Thus, in conditions 2 and 4 a cluster of features defined attribute A in the design. The normality of A was probed by shape (e.g., "Is the shape normal?").

Discriminability data were collected in a pilot experiment with 6 subjects, to ensure that the differences between the norms in attribute A in conditions 2 and 4 (where this attribute is defined by a conjunction) were not more discriminable than the differences in attribute A in conditions 1 and 3, respectively. Subjects were instructed to assign the two norm stimuli to different response keys. A series of 50 trials was then presented, with a single stimulus shown on each.

All norm pairs actually used in the normality experiment satisfied the following condition: attribute clusters defining A were not more quickly distinguished from each other than single attributes defining A in the comparable condition. Reaction times for clusters were either equal to, or longer than, reaction times for the single-attribute comparison.

The normality results are shown in Table 1.1.

Table 1.1

	P?		P-		P+	
	A+	B+	A?	B?	A?	B?
1	100	0	75	93	79	7
2	93	0	79	89	82	11
3	64	32	75	79	75	29
4	82	25	86	82	75	36

Conditions 1 and 2 show dominance but not contingent coding, and also indicate that A is normal even when size is not. This replicates previous results for size and shape and extends the previous finding of shape+color and size to cases with low discriminability. No differences were observed between conditions 1 and 2. The results for conditions 3 and 4 show a similar pattern to 1 and 2. There is no sign of the contingent coding that we expected in condition 4.

It seems that the link between A and B attributes is so strong in all conditions that normal pairing dominates position (the 3rd and 4th columns). However, abnormal values on B are not sufficient to make A abnormal (column 5).

<u>Normality and individuality</u>

Four conditions in the present series investigated normality for a particular class of highly-individuated stimuli -- words. Again, all four conditions used position as the third attribute.

Conditions were as follows:
condition 5. A = word; B = size+color, prompted by size
condition 6. A = non-word; B = size+color, prompted by size
condition 7. A = word; B = color
condition 8. A = word; B = underlining type and color

The results are presented in Table 1.2.

Table 1.2

	P?		P-		P+	
	A+	B+	A?	B?	A?	B?
5	86	18	89	100	46	7
6	82	7	86	75	57	7
7	96	0	79	93	68	14
8	96	0	75	96	82	7

In all conditions the word dominated other attributes. This was also true for the non-word in condition 6, which indicates that familiar associations and meaning are not the mediators of normality in these conditions. As in conditions 1 to 4, abnormal secondary attributes do not make the word abnormal. There is some tendency for contingent coding in conditions 7 and 8, but there is still a strong tendency to respond that the word is normal if its secondary attributes are (more so if it is supported by a cluster of attributes, as in condition 5). We had expected that condition 8 would provide the most likely condition for contingent coding. The observed result, though in the expected direction, was much weaker than anticipated.

Our inability to get control of contingent coding was disappointing. I decided to set aside for the moment the pursuit of the normality measure and to focus on other experimental problems in the same general area. I expect to return to the normality design or to some variant of it in the coming year.

Section 2: Discriminability and Similarity
O'Curry and Kahneman

The question we seek to answer in this research arose in studies of normality judgments and spontaneous categorization, reported last year. Will spontaneous categorization of multidimensional stimuli be along the dimension with the most highly discriminable values, or will some dimensions dominate categorization judgments, irrespective of the discriminability of values on other dimensions? Our previous work indicated that for some cases, global similarity was ignored in normality judgments. This occured most often in conditions involving small differences in shape but large differences in color or other attributes. Shape dominated normality judgments completely. This is in accord with Landau, Smith, and Jones (1988), who found that children over two years of age classify objects by shape, even when probe objects are twelve times as large as the standard, as well as earlier work by Heidbreder (1948, 1949). Although we reported last year some attempts to measure similarity and to distinguish it from probability, these efforts were of limited value, because the stimuli we used in the normality work and in related measurements of similarity were always identical in one attribute. There are many indications in the literature that feature identity is a special case Shepard, 1964; Smith, 1989).

The primary goal of this research is to more clearly delineate the relationships between discriminability, judged similarity and normality, and categorization. At the same time, we would like to better understand the role different attributes of objects play in classification. The research reported here addresses only the relationship between discriminability and similarity. Experiments planned for the immediate future will deal with the extension to categorization.

Spatial models of similarity assume that the dissimilarity between two objects is monotonically related to the distance between the representations of the objects in a multidimensional psychological space (Davison, 1983). The further assumption is made that similarity is simply the inverse of dissimilarity. This sort of model is the foundation of multidimensional scaling. Although spatial models are not formally explicit about how discriminability and similarity are related, the operational assumption is often made that higher discriminability results in larger distances in the psychological space, leading to low similarity (Nosofsky, 1988; Smith, 1989). There is also no obvious way to account for the special role of identity in these models, although Shepard (1964) proposed that selective attention may account for effects of identity matches in judgments of overall similarity of analyzable stimuli. (See Smith, 1989 for a more recent attempt to deal with this problem).

Tversky (1977) offered a set-theoretic model that accounts for some anomalies of distance models, such as violations of the triangle inequality. His feature-contrast model represents similarity as a weighted linear combination of the common and distinctive features of the two objects being compared. Tversky's model deals with identity matches as common features, and is uncommitted on the relationship between similarity and discriminability.

Recently, a third model of similarity, based on an extension of signal detection theory, has been proposed by Ashby and Perrin (1988). Similarity is seen as the overlap of perceptual distributions, and is said to be directly linked to the confusability of stimuli. Ashby and Perrin's model makes the strongest claim about the link between discriminability and similarity - that they are directly related. They offer no way to deal with identity matches on a dimension as a special case of similarity unless a subject has seen the entire array of stimuli being judged.

Some work by Garner and his associates in the late 1960's touched on the issue of the relationship between discriminability and similarity (Imai & Garner, 1965; Handel, 1967; Handel & Imai, 1972; Podgorny & Garner, 1979), but with a single exception, discriminability was assumed from the structure of the stimuli, rather than measured objectively. Podgorny and Garner (1979) did use discrimination reaction time, but used an insufficient number of replications (only two) for any substantive claims.

Rather to our surprise, then, the obvious question of the relation between similarity and discrimination still remains to be explored empirically. Our research was designed to explore the link between a reaction-time measure of discriminability and judged similarity, and to examine the role of identity matches in judgments of similarity. In addition, we wanted to know whether the hierarchy of attributes that we had sometimes observed in normality judgments would be evident here.

Subjects were presented with a subset of a 6 x 6 stimulus matrix and performed a same-different judgment reaction time task followed by a similarity rating task. A monotonic relation between discriminability and similarity implies that high similarity ratings should correspond to long reaction times, e.g., that there should be an ordinal correspondence between the two responses.

Method

Twenty-eight Berkeley undergraduates participated in three different versions of the experiment in exchange for course credit.

The experiment was displayed on a Mitsubishi color monitor controlled by an IBM AT computer with an Artist Board graphics card.

Because a 6 x 6 stimulus matrix has 630 different pairs of stimuli and reaction time data requires collection of several responses to the same stimulus pair, we devised an abbreviated version of the standard "all possible pairwise comparisons" technique. A subset of the matrix, comprising the top three rows and three rightmost columns was used for a total of 27 stimuli (see Figure 2.1). One stimulus served as the "core", and all the other stimuli were compared to it. There were 26 "different" trials and 16 "same" trials per block, for a total of ten blocks. The same stimulus array was used for the reaction time task and the similarity task, except that no identical pairs were presented for the similarity task. For the similarity task, subjects rated each pair twice.

Insert Figure 2.1 about here.

The display consisted of the standard stimulus and a test stimulus centered in the monitor screen, with the standard above the test stimulus separated by 40 mm. Displays were response terminated.

In the reaction time task, subjects pressed one key if the stimuli were the same, and another if they were different. If a response was incorrect, auditory feedback was given. Instructions, both written and verbal, stressed the importance of accuracy over speed. In the similarity task subjects rated the similarity of pairs of stimuli using a 0-9 scale, where 0 meant "not at all similar" and 9 meant "very similar".

To date, two conditions have been run: color-shape and color-texture. In the color-shape condition, stimuli were triangles of approximately the same area varying in base and height and along a blue-red dimension. In the color-texture condition, stimuli were checkerboards varying in density of check pattern and the same blue-red dimension as the color-shape condition, using a different color for the core stimulus.

A third version using a 5 x 5 matrix of stimuli was run in order to be sure that our abbreviated design was not confounding our results in any way, and to obtain a multidimensional scaling solution. This was run using the stimuli for the color-shape condition, with all possible pairwise comparisons. The results of this version replicated those of the shorter version and will not be discussed separately.

<u>Results</u>

We were looking for two patterns in the data. First, we wanted to see whether similarity judgments corresponded ordinally to reaction time in the same-different task, particularly in the case where a test stimulus matched the "core" stimulus on either dimension. Second, we wanted to compare both types of responses across the different dimensions to see if there was evidence of differential impact of dimensions on similarity judgments when reaction time was equal.

Tables 2.1 and 2.2 detail the results for the color-shape and color-texture conditions respectively. The data show some clear violations of monotonicity, most notably among the four stimuli that surround the core in Table 2.1. There are dissociations of similarity and discriminability throughout the range of both variable: for the 5 stimulus pairs with mean reaction times from 571 - 580 ms in the color-shape condition, mean similarity ratings range from 1.79 to 4.25. A similar, though less dramatic pattern can be found in the checkerboard data.

With respect to the question of differences between attributes in determining responses, the color-shape data indicate that shape contributes more to judged similarity than color, given equal discriminability and a match on either color or shape. For example, stimulus pairs (2,3) and (4,5) do not differ significantly on mean reaction time with 579 and 591 ms respectively. (Stimuli are referred to by their row and column positions in the stimulus matrix.) However, the respective mean similarity ratings are 4.25 for the color match and 6 for the shape match, $t(11) = 2.37$, $p = .05$.

When stimuli do not share a value with the core stimulus, there is no evidence of a differential contribution of attributes.

The color-texture data show a slightly greater contribution of texture than color to rated similarity. This comparison is not as clear because there are few stimuli that can be equated on reaction times. The stimuli (2,1), a color match, and (6,5), a texture match, are not significantly different with mean reaction times of 470 and 460 ms, but mean similarity ratings are 4.62 and 6.17, $t(11) = 2.663$, $p = .022$. More stimuli can be found that are not significantly different on rated similarity, while discrimination reaction times differ by a highly significant amount. Again, this result is limited to cases where there is a match with a value of the core stimulus.

Table 2.1 Results for Color-Shape

Results are for each stimulus compared to the standard (2,5). Top number is mean reaction time in milliseconds. Bottom number is mean similarity rating. A programming error led to the loss of similarity rating data for stimulus (1,1). (n = 12)

SHAPE →

Column		1	2	3	4	5	6
Row 1	↑	527	572 2.71	602 3.5	611 4.95	715 7.04	(not run)
Row 2	C O	548 3.04	575 3.25	579 4.25	773 5.97	CORE	805 5.58
Row 3	L	538 2.12	530 2.79	557 3.67	624 5.14	728 7.4	642 4.96
Row 4	O R				550 4.33	591 6	579 3.96
Row 5	↓				539 2.91	558 3.79	538 2.29
Row 6					571 1.79	564 3.62	552 1.75

Mean "same" reaction time for core stimulus = 689 ms.

Table 2.2 Results for Color-Texture

Results are for each stimulus compared to the standard (2,5). Top number is mean reaction time in milliseconds. Bottom number is mean similarity rating. (n = 12)

CHECKERBOARD DENSITY →

Column		1	2	3	4	5	6
Row 1		450	461	466	510	544	502
	C	3.08	3.04	4.29	4.54	7.37	3.58
Row 2	O	470	496	533	676	CORE	655
		4.62	5.17	6.29	7.12		6.45
	L						
Row 3		428	445	445	465	440	454
	O	.92	1.79	3.08	3.33	6.46	2.12
Row 4	R				453	450	455
					3.37	6.16	1.83
	↓						
Row 5					463	459	464
					3.37	6.29	2.54
Row 6					440	460	465
					3.42	6.17	1.79

Mean "same" reaction time for core stimulus = 517 ms.

To summarize, in both conditions dissociations between similarity ratings and discrimination reaction times were obtained, with the strongest effect along the row and column that matched the core stimulus. In addition, the color-shape condition showed that shape contributed more to similarity judgments than color when reaction times were equal. This is clearest when comparing trials that share either color or shape with the core and are equally discriminable (by reaction time). When stimuli are equally discriminable, a shared value on shape contributes more to judged similarity than a shared value on color. The color-texture results are not as clear as those from the color-shape condition, but there is an indication that a match on texture may influence rated similarity more than a match on color.

The dissociation between discrimination reaction time and similarity judgments suggests that the relationship between discriminability and similarity is more complicated than assumed by Ashby and Perrin's model. The higher similarity ratings for stimuli that share a value on either dimension with the core stimulus confirm the special role of identity in judged similarity. In addition, the results for the color-shape condition indicate that similarity judgments are susceptible to the same type of differential effect of attributes as normality judgments. Whether this is due to differential weighting of dimensions, or a hierarchical ordering of attributes cannot be distinguished from these data.

Our ultimate goal in this research is to map the relationship between discriminability, similarity, and categorization. Most models of categorization rely on similarity, either to a prototype or to other exemplars, to predict categorization. Our suggestion is that in some cases judged similarity may itself rely on categorization. Specifically, an identity match may lead to spontaneously categorizing a stimulus, resulting in a judgment of higher similarity.
The hypothesis, to be studied in future work, is that the weighting of dimensions and of feature differences in similarity is generally intermediate between the corresponding weights derived from discrimination and from categorization tasks.

Section 3: Processing of dimensional information in priming
Kahneman, with Gibbs and Treisman

In previous work undertaken in collaboration with Anne Treisman and Brian Gibbs, I have studied an effect that we labeled 'object-specific priming'. The target stimulus in most of our studies was a letter that was to be named as quickly as possible. The target was contained in one of several objects, e.g., outline squares. The essential feature of the situation was that the whole set of squares had just arrived from an original position -- the movement time ranged in different studies from 80 to 600 msec. While the squares were stationary in their initial positions and just before they started to move, letters briefly appeared in them. These are the primes. The main result of our study was that there was a priming effect of presenting the target letter in the initial display, but only if the prime appeared in the same square that later contained the target. Indeed, the standard result with letter stimuli (words are different) is that presenting the target letter in the 'wrong' object yield little or no benefit compared to a control condition in which the target is not primed at all. Hence the label 'target-specific priming'.

An obvious question about this priming effect is the level of encoding at which it arises. Applying a fairly standard diagnostic, Treisman and I conducted an experiment to test whether the object-specific priming effect is also case-specific. We varied the case of the prime and of the target independently, and observed that priming was diminished when the case varied between prime and target. Brian Gibbs followed up with a Master thesis in which he required subjects to respond to a particular feature of the stimulus (e.g., its shape, size or color), allowing the prime and the target to vary in response-irrelevant attributes. We considered these results equivocal, and decided to clarify the issue in a series of experiments, which was conducted in the fall of 1989.

Insert Figure 3.1 about here

The common feature of the experiments is that the displays consist of four white squares, which contain colored letters. As illustrated in Figure 1, a priming pattern is first shown around a fixation cross. It is then removed, and a target field is immediately shown. There are four possible positions of the target field -- computed by moving the whole pattern so that one of the four initial squares is centered on the fixation cross. The sequence of displays yields a powerful impression of coherent motion. Object-specific priming can be studied by comparing performance in several cases: (1) when the target matches the prime stimulus shown in the same object; (2) when the target matches the prime stimulus shown in another square; (3) when the target does not match any of the primes. Figure 3.1 illustrates the first of these cases. It is also possible to construct tasks in which the prime and the target are not physically identical, but differ in case, color, size or other attributes. The project was designed to study the effect of such manipulations of prime-target resemblance.

Experiment 3.1 -- Size priming with shape/character varied

In this experiment the stimuli were two red capital letters (Y and O), in two sizes, 3.3 and 6.5 mm tall. Each letter was centered in a white square measuring 20.3 mm. The priming display always contained two large and two small characters. It was presented for 100 msec and was immediately followed by the target field (see Figure 3.1). The subject indicated the size of the target character marked by the cross-hairs, by pressing one of two keys assigned to different hands. Table 3.1 presents the reaction time for 'large' and for 'small' responses, as a function of the agreement between the target and the character presented in the 'same' square in the original display.

Table 3.1 -- Reaction time to size discrimination with irrelevant variation of shape/character

Agreement		Target Size		
Size	Shape	Large	Small	Mean
+	+	511	470	491
+	-	506	480	493
-	+	517	494	506
-	-	524	490	507

The results are unequivocal: there is a substantial object-specific priming effect (14 msec, $t(15) = 4.52$, $p<.01$) and not a trace of interaction with the shape of the stimulus.

Experiment 3.2 -- Color priming with shape/character varied

The design of the experiment was the same as the preceding one. The subject now responded to the color of the character that appeared in the target position, by pressing a key. The possible colors were red and green. The temporal parameters were the same as in the previous experiment.

Table 3.2 -- Reaction time to color discrimination with irrelevant variation of shape/character

Agreement		Target Color		
Color	Shape	Red	Green	Mean

+	+	481	461	471
+	-	480	475	477
-	+	517	489	503
-	-	508	486	497

Again, the results are quite clear. There is a substantial object-specific priming effect (26 msec, $t(15) = 6.36$, $p<.01$) but the interaction of color and shape similarity is not significant ($t = 1.54$). There is no evidence that object-specific color priming is affected by the identity of the prime and target characters.

Experiment 3.3 -- Letter priming with case variation and key response

The accumulation of evidence for independence in the processing of different dimensions of the stimulus was sufficiently impressive to justify a partial replication of the Kahneman-Treisman experiment sutdy of the effects of case identity on object-specific priming. The earlier experiment had been conducted with a different display, in which only two squares were shown in 'real' motion, and where the subject made a vocal response to indicate reading the letter. For the present experiment we adopted the display and design of the two preceding studies. There were four squares, and two possible target characters (G and D). The subject responded to the identity of the target letter by pressing a key. The exposure duration of the prime was 100 msec. The results are shown in Table 3.3.

Table 3.3 -- Reaction time to letter discrimination with irrelevant variation of case

Agreement		Target case		
Letter	Case	Upper	Lower	Mean
+	+	502	498	500
+	-	511	502	507
-	+	537	526	531
-	-	549	528	539

The now familiar pattern of results is observed again: a robust object-specific priming effect of 30 msec ($t(11) = 4.02$) when the prime and the target have the same case, 32 msec when the case varies ($t=4.59$). There is of course no trace of an interaction.

Experiment 3.4 -- Letter priming with case variation, vocal response

We now decided to replicate the original case experiment, using a vocal response, in the four square display, in an attempt to identify the boundary conditions for the interaction of object-specific priming with case identity. The display conditions were the same as in the preceding study but the vocabulary of possible stimuli was explanded to 8 letters (B,D,G,H,N,R,Q,T), and vocal RT was measured. Table 3.4 shows what happened. The larger vocabulary allows a control condition in which the target letter is not presented at all in the priming display. This is useful, because the object-specific effects observed in the key-press experiments are the sum of object-specific priming (when there is a match between prime and target) and inhibition (in cases of mismatch). Results for this control condition are shown in the bottom row of the Table.

Table 3.4 -- Vocal reaction time in letter naming with irrelevant variation of case

Agreement		Target case		
Letter	Case	Upper	Lower	Mean
+	+	479	481	480
+	-	481	473	477
-	+	491	490	491
-	-	494	483	489
Unprimed letter		492	484	488

The comparison with the control indication indicates that there is no trace of priming except when the prime and the target are shown in the same object. The results also show that there no significant inhibition is produced by presenting the target in the 'wrong' object. The object-specific priming is smaller than in some of our previous work, is the same when case is identical and when case is different (11 and 12 msec, respectively), and is significant in both cases ($t(11) = 2.75$ and $t = 3.30$, respectively). The results are quite consistent with the other experiments in this series, but diverge from those previously obtained by Kahneman and Treisman, which used a somewhat different display, where the object-specific priming was 21 msec when case was identical and 8 msec when it varied between prime and target. We are at the moment at a loss to explain the difference.

Experiment 3.5 -- Categorization of characters with case varied

In the final experiment in this series, we returned to the key-press response. The subject's task was to press one key for letters in the first half of the alphabet (A,E,G vs N,Q,R). The priming display and the target display both consisted of two letters each from each category, one in upper and one in lower case. Except in the last condition of Table 3.5, the target letter was always present in the priming display, sometime in the same case, sometime in a different case. The results are shown in Table 3-5.

Table 3.5 -- Categorization time with variation of case

Agreement within target object	Target letter in priming field	
1) Same letter	same case	531
2) Same letter	different case	535
3) Same category	same case	551
4) Same category	different case	543
5) Same category	absent	546
6) Different category	same case	551
7) Different category	different case	553
8) Different category	absent	555

There is significant priming when the target letter that is to be categorized has been presented in the same object, both when case is the same (16 msec, $t(19) = 3.55$) and when case varies (13 msec, $t = 2.26$). The effect of case identity is not significant ($t = 1.00$). There is a small but probably reliable advantage of showing the target in a square that previously contained another letter in the same category: the overall difference between rows 3,4,5 and rows 6,7,8 averages 6 msec, $t(19) = 2.12$, $p<.05$. However, the advantage of priming by the same letter is significantly greater (for the comparison of rows 1,2 to rows 3,4, $t(19) = 4.76$).

The findings of this experiment further confirm object-specific priming (or interference). They also provide evidence that the effect is produced in part by pooling of response tendencies or by high-level categorization -- the category priming effect observed here, although quite small, is theoretically significant. The results also indicate that there is something special about case -- a conclusion also suggested by other findings in the reading literature. It could have been argued that the only thing that the upper and lower case representations of a letter have in common (if physically dissimilar) is that they map onto the same response. But merely mapping onto the same response could not explain cross-case priming, because the different letters in a category also map onto a response, in the present experiment. The upper and lower case versions of a letter appear to be 'the same', for the purpose of priming, just as a green and a red version of the letter would be. The absence (or weakness) of within-category priming must be interpreted together with the total independence of dimensions processing observed in the other experiments of this series. Taken as a set, these findings suggests that priming occurs at the level of what Treisman calls 'feature maps'.

Section 4: The Language of Counterfactuals: 'Almost' as an indicator of propensity and proximity (Kahneman and Varey)

One of the central tenets in norm theory (Kahneman and Miller, 1986) is that the normality of an event is assessed by comparing it to the norms that it evokes retrospectively. The treatment of counterfactuals is a central problem in that theory. For the past year Carol Varey and I have been engaged in the study of a particular class of counterfactual assertions. Many situations are aptly described by such phrases as 'Team A almost won', 'Tom almost died', 'Joan almost got married to Ted'. Use of the word 'almost' to describe achievements that came close to happening is an example of spontaneous generation of counterfactual alternatives to the actual outcome. The near-outcome is so readily available that the counterfactual is not expressed as a counterfactual conditional with a specified antecedent. We call these assertions close counterfactuals, and the attempt to explore what can be learned from them about intuitive notions of probability and causality has been a focus of my effort this year under the AFOSR contract. Much of the effort involves conceptual analysis, but we have also run several questionnaire studies eliciting intuitions about appropriate uses of 'almost'. A paper describing some of the results of these studies has been accepted by the Journal of Personality and Social Psychology, and is currently under final revision.

A treatment of the psychology underlying close counterfactuals turns out to be inextricably linked with an investigation into some aspects of causality and probability. Counterfactual assertions normally invoke causal beliefs and assign degrees of probability or plausibility to unrealized outcomes. Accounts of causality, in turn, often invoke counterfactual beliefs (for example, about what would have happened in the absence of a putative cause) as well as notions of conditional probability. Finally, notions of objective probability often rest on intuitions about causal systems. The present studies are concerned with a psychological study of this nexus of issues.

Our approach combines some simple phenomenological observations and a basic linguistic inquiry into the conditions under which close counterfactual assertions are appropriate. The genre is not unknown in psychology: Heider (1958) and Schank and Abelson (1977), in particular, have successfully carried out ambitious exercises in this vein. Studies of what people mean when they say that 'John went to the restaurant', or when they use the words 'can' and 'try' have contributed significantly to our understanding of how people think about events and actions. In the present studies we examine the use of the word 'almost' to explore how people think about counterfactuals, probability and causation.

We restrict our discussion of 'almost' to cases in which the actual outcome X, or the near-outcome Y, is an achievement (see Lyons, 1977; Miller & Johnson-Laird, 1976; Vendler, 1967) -- a change of state that occurs at a particular moment, usually as the culmination of a longer causal episode. We analyze the beliefs that a speaker expresses by the assertion that an individual almost died, or almost missed a deadline, and examine what such beliefs can teach us about the cognitive representation of uncertain events and of causal propensities.

Method

Students at the University of California at Berkeley served as subjects. They were recruited by posters displayed outside the student union offering a small payment for immediate completion of a questionnaire. Respondents were given instructions followed by approximately fifteen questions. An illustration is given below:

> In the following questions you are asked to rate statements on a scale from "Appropriate" to "Very Peculiar". A set of statements is presented for each question. You are to rate whether the last statement fits well with those that preceded it.
>
> (1) At the end of a long game of chance, John could have won the whole pot if a die that he rolled showed a six. The die that he rolled was loaded to show six 80% of the time. John rolled it and it showed a two. John almost won the whole pot.
> Appropriate ___ Somewhat Peculiar ___ Very Peculiar ___
>
> (2) Tom almost died but in fact he was never in real danger.
> Appropriate ___ Somewhat Peculiar ___ Very Peculiar ___

Some of the questions were paired with similar questions in a between-subjects design. For example, one variant of example 1 provided the same scenario, but asked subjects to judge the statement 'John almost threw a six'. Some subjects were also asked to make within-subject comparisons. An example follows:

> (3) John played in a game of chance involving six die throws. He would have won the whole pot if he had thrown six sixes in a row. He threw five sixes and a five.
>
> Fred played in a game of chance involving five die throws and a coin toss. He would have won the whole pot if he had thrown five sixes and tossed heads. He threw five sixes and tossed tails.
> Which of the following is more appropriate:
> a. John almost won the whole pot.
> b. Fred almost won the whole pot.
> c. Both are equally appropriate.

Results

We next briefly discuss some major conclusions of our analysis of close counterfactuals, illustrating them with selected examples of the data we have collected.

<u>The objective stance</u>. close counterfactuals are treated as a matter of objective fact, in the sense that their truth or falsity does not depend on the beliefs of any individual or community. The event that almost happened did not really happen, and in that sense does not belong to reality -- but the fact that it almost happened is treated as real, not as a mental event such as a fantasy or an imagining (Johnson & Raye, 1986).

(4) Everyone thought Phil almost died.... but in fact he was never in real danger.
Appropriate 69% Very peculiar 10% (N = 29)

(5) Tom almost died.... but in fact he was never in real danger.
Appropriate 7% Very Peculiar 66% (N=29)

An objective attitude similar to that which is applied to counterfactual statements is also adopted when people talk of causes -- these are viewed as facts about the world, not as subjective events. An objective attitude also characterizes many probability statements -- when probability is taken to describe a disposition or causal propensity of a system rather than a state of belief. (Contrast 'the probability that the ball drawn from the urn would be red was .60' with 'the probability that the Nile would be longer than the Amazon was .60'.)

<u>Propensities and dispositions</u>. We draw a distinction between two kinds of assessment of the probability of a particular outcome at the end of an event episode. A <u>disposition</u> for the focal outcome is the probability of the focal outcome as assesses prior to the initiation of the episode. A <u>propensity</u> for the focal outcome is the probability of the focal outcome as assessed from event cues during the course of the episode.

The key observation about close counterfactuals is that strong prior dispositions are not sufficient to support the statement that an outcome almost occurred. Event cues supporting a strong propensity are required. This is illustrated by the following examples:

(6) John rolled a die that was loaded to show six 80% of the time. John rolled it and it showed a two.... John almost threw a six.
Appropriate 6% Very peculiar 62% (N = 32)

(7) Tom almost registered for the tournament. He would have won if he had played... Tom almost won the tournament
Appropriate 10%   Very peculiar 62%   (N = 40)

<u>Proximity, progress, and sensitivity to obstacles</u>. People are sensitive to a dimension that is commonly described as the distance between states of the world at different points in time. The representation of causation as movement through space and as the overcoming of obstacles along the way is involved in a rich family of metaphors -- 'coming close' is one of many. We have examined some of the factors that control impressions of distance, including the number of intervening causal stages, the decisiveness of the intervening events and the possible obstacles in the path to the focal outcome.

One series of questions focused on cases in which an individual 'wants X' or 'considers doing X'. We were interested in identifying cases in which such intentional states would support the statement that the individual 'almost got X' or 'almost did X'. Some examples follow

(8) Martin considered getting married to Meg. Martin almost married Meg
Appropriate 14%   Very peculiar 34%   (N = 29)

(9) Neil considered not getting married to Amanda. Neil almost didn't marry Amanda
Appropriate 62%   Very peculiar 19%   (N = 32)

(10) Fred considered stealing his child's savings. Fred almost stole his child's savings.
Appropriate 30%   Very peculiar 16%   (N = 32)

(11) Ned considered breaking into a bank vault. Ned almost broke into a bank vault
Appropriate 18%   Very peculiar 44%   (N = 32)

Consideration of an action supports the assertion that it was almost performed only when (1) a relatively small number of steps intervene between the thought and the action; (2) consideration may be assumed to suggest a possible desire to perform the action; and (3) when the individual who considered the action could reasonably be thought to be capable of it. In a romantic relationship, either individual has the power to terminate it and thinking about breaking up may imply dissatisfaction. An individual who considers marrying someone, or even clearly wishes to marry that person, may be quite far from being able to carry out the intention. Our subjects' responses clearly differentiate these cases. Subjects are also sensitive to the fact that much more remains to be done, beyond mere consideration, for the project of breaking into a bank vault than for stealing one's child's savings.

Conclusions

On the basis of the data collected in our surveys and general linguistic intuitions, we claim support for the following conclusions:
(1) Counterfactuals, causes and (some) probabilities are treated as facts about the world, not as constructions of the mind.
(2) The absence of perfect hindsight indicates that people attribute inherent uncertainty to some causal systems -- what happened is not treated as necessary or inevitable.
(3) Probabilities of outcomes can be assessed on the basis of advance knowledge (dispositions) or of cues gained from the causal episode itself (propensities). The distinction is critical to the use of 'almost', which requires the attribution of a strong propensity to the counterfactual outcome.
(4) Cues to propensity are the temporal or causal proximity of the focal outcome, and any indications of accelerated progress.
(5) A general schema of causal forces competing over time is applicable to many achievement contexts.
(6) Dispositions that are not supported by event cues will be neglected in retrospective judgments of outcome probability.
(7) Conversational pragmatics allow more latitude in the acceptance of 'almost' when the speaker is emotionally involved in the near-outcome.

We are also investigating the following plausible hypothesis:
(8) In articulated scenarios (consisting of a sequence of branching event nodes), 'almost happened' will only be appropriate for an outcome with a strong propensity at the last node prior to the final outcome.

Section 5: Studies of comparison and choice

The study of comparison processes was initiated last year by Maria Stone, and was continued this year. A paper on that work is in prepation for publication. As will be evident, this work adopted ideas from Jim Sherman. A new departure this year was a collaborative
effort with Sherman, which links the topic of comparison with the topic of choice, and has yielded highly promising results.

The role of attention in comparison -- Stone and Kahneman

Comparison is an important aspect of the encoding and interpretation of experience. Comparison is also a skill that is executable under voluntary control: when instructed, one can choose a subject or topic, and compare it with a standard or referent, on specified dimensions or in a general search for differences. There is usually more than one way to express the results of a comparison, e.g., "A is larger than B" or "B is smaller than A". For many relationships, however, one of the directions is is used more often and appears more natural than the other (D'Arcais, 1970; Talmy, 1984; Jackendoff, 1988). There is a compelling intuition, however, that the distinction between topic and referent does not only arise at the stage of choosing a verbal description for a comparison; the topic and the referent are processed differently in the comparison itself.

The research carried out by *Maria Stone* investigated the general hypothesis that the allocation of attention is a determinant of the assignment of roles to the objects of comparison: the attended object tends to become the topic or subject of the comparison; the relatively unattended one becomes the referent. The main methodological idea was adopted from Agostinelli, Sherman, Fazio and Hearst (1986), which exploits an asymmetry noted by Tversky (1977): the similarity of A to B is reduced by features that are unique to the topic (A) more than by features that are unique to the referent (B). Similarity data or same/different judgments can therefore be used to diagnose which of the two elements of a comparison serves as a topic; the difference between two stimuli will be noted more readily if the unique features that distinguish them belong to the topic rather than to the referent.

In experiments described in the preceding report, Stone used modified Chinese characters, which are readily modified by adding or deleting strokes. The subject indicated by a key press whether two figures were identical or different. The displays that she used and here main results are listed below.

1) A moving figure and a stationary one are presented together. A difference was detected faster if the extra feature belonged to the moving figure.

2) Two characters are shown in an initial display; 960 msec later, a third figure is added, which is to be judged as different from

both or similar to one of them, The difference was noted more quickly when the extra feature belonged to the more recent figure.

3) A single character is shown for 480 msec, followed by a mask of 480 msec and a blank ISI of 960 msec. Under these conditions, the detection of a difference was faster when the first stimulus was complex. This result was predicted, on the assumption that subjects would engage in active encoding of the first stimulus, when it was expected to be masked.

4) A single character is shown for 480 msec, followed by the other character after an ISI of 480 msec. Under these conditions, there was no interaction with complexity, a result that we interpreted as indicating that the tendencies to compare the first figure to the second of the second to the first were about equally strong.

In research carried out this year, Maria Stone completed two experiments that will be included in the report of the work to be submitted shortly for publication. One experiment investigated the effect of cueing the location of one of two stimuli presented simultaneously. A fixation cross was presented on one of eight possible locations on a circle 6.8 cm in diameter, on a monitor screen viewed from a distance of 60 cm. The fixation cross was on for 170 msec, and was immediately replaced by a field including one figure in the fixated location and another at the other end of a diameter. Table 5.1 presentes the results of the experiment. For comparison, we include the results of the experiment in which attention was controlled by moving one of the characters.

Table 5.1
Same-different judgments as a function of complexity and attention

response	same		different	
attended object	complex	simple	complex	simple
FIXATION				
reaction time	1152	1026	982	1013
error rates (%)	2.9	2.0	4.5	5.4
MOTION				
reaction time	1269	1077	1003	1109
error rates (%)	2.0	2.1	1.1	4.7

The effect of the fixation cross is in the predicted direction: subjects were faster responding "different when the location of the complex figure was cued) but the effect is small and only marginally significant ($t(11) = 1.80$, $p<.05$, one tailed). The difference between the effects observed in the two experiments is statistically significant.

Why is cueing less effective than motion? An important difference is that cueing exerts its influence only on the initial allocation of attention, whereas the pull of the moving object endures throughout the processing of the comparison. We also speculate that attention is normally drawn toward the more complex figure. The stronger and maintained effect of motion would counteract this attraction to the complex figure more effectively than the advance cue to location. This hypothesis will be tested by presenting probe stimuli at the location of the complex and the simple figures.

A possible interpretation of subjects' performance in these experiments is that they detect a difference between figures by comparing the number of features they contain, without identifying the figures, and without paying attention to the specific features that distinguish the figures from one another. Even if this were the case, the fact that the detection is easier in one direction than in the other would be interesting. But the results reported above would then have little to do with Tversky's comparison model, or with the effects observed by Agostinelli et al.

To check the hypothesis that performance is mediated by a comparison of the number of features, an experiment was conducted in which this cue was no longer sufficient for a 'different' response. Some of the paired figures were constructed by adding different features to the same basic figure. These pairs cannot be discriminated by number of features, and their presence in the experiment must reduce the reliance on this cue. The first figure appeared 960 msec before the second, and remained on the screen until the trial was terminated by the subject's response. This arrangement is designed to promote the assignment of the role of topic to the second stimulus.

The main results of the experiment are shown in Table 5.2

Table 5.2
First/First+Second with characters of intermediate complexity.

Condition	First figure has:	Second figure has:	RT	%error
'same'				
1	2 extra features	2 extra features	1267	2.33
2	1 extra feature	1 extra feature	1174	1.75
3	0 extra features	0 extra features	1061	1.42
'different'				
4	2 extra features	0 extra features	945	3.75
5	0 extra features	2 extra features	870	2.25
6	1 extra feature	0 extra features	1019	8.92
or	2 extra features	1 extra features		
7	0 extra features	1 extra feature	986	5.42
or	1 extra feature	2 extra features		
8	1 extra feature	1 extra feature	979	2.75

As predicted, reaction times for condition 4 (complex, simple) are significantly slower than reaction times for condition 5 (simple, complex), $t(11)=2.36$, $p<.025$. A trend in the same direction is observed on error rates, as well ($t(11)=1.27$). Conditions 6 and 7 show a similar pattern in results, there is a trend in the right direction on reaction times ($t(11)=1.58$), and there is a significant effect on error rates ($t(11)=2.55$, $p<.025$). The effect is present on reaction times for the more discriminable pairs of stimuli and on error rates for the less discriminable pairs. The most important result is that condition 8 is slightly faster, and not significantly different from condition 7. This is the result predicted from the idea that the features of the topic play a privileged role in the discrimination. If subjects had used complexity differences as a cue, condition 8 should have been much harder than condition 7. The results support the interpretation of the interaction between complexity and attention as indicating that the attended figure is indeed treated as the topic of the comparison.

This series of experiments generally supports the notion that the roles of subject and referent are distinguished in cognitive processing, not only in language. The diagnostic proposed by Agostinelli, Sherman and their colleagues served us well in this connection. In the next experiment, conducted in collaboration with Jim Sherman, a related diagnostic turned out to be ambiguous in ways that had not been suspected before.

Feature comparison and choice -- Sherman and Kahneman

In a follow-up to the Agostinelli et al study, Houston, Sherman and Baker (1989) extended the same ideas to a choice paradigm. Their reasoning was that choice between options involves a comparison, in which one of the options is presumably the subject and the other the referent. Their paradigm involves two sets of choice problems. The choices in one set involve two objects that share their positive features but have unique negative features. In the other set paired choice objects share their negative features but have unique positive features. With sequential presentation of the objects of choice, the second object should generally be the topic or subject of the comparison. Again applying Tversky's idea that the unique features of the topic are weighted more than the unique features of the referent, Sherman and his students derived the prediction that the subject of the comparison should be preferred when both objects have unique positive features, because the positive feature of the referent would be neglected. By the same logic, the referent should be preferred if both stimuli have unique negative features. Houston, Sherman and Baker (1989) conducted a series of experiments in this general paradigm, which they viewed as supportive of their analysis of choice as comparison.

Sherman presented this work in a colloquium at Berkeley in 1988, and I found it quite intriguing. His approach to choice seemed quite different from the one that I have developed in joint work with Amos Tversky and with other colleagues, which focuses on the notions of reference state and on loss aversion, the differential treatment of gains and losses (Kahneman, Knetsch and Thaler, in press; Kahneman and Tversky, 1984; Tversky and Kahneman, in press). In our approach there is also a notion of topic and referent, but the referent is generally the status quo or endowed position. Our prediction is that there should be a general bias favoring the status quo (Samuelson and Zeckhauser, 1988) because the differences that favor it over alternatives are treated as disadvantages of the latter -- which loom larger than corresponding advantages.

Sherman and I discussed the apparent conflict between our findings. We agreed on the plausible hypothesis that the discrepant results occur because my experiments involved an explicit reference state whereas those of Sherman's group did not. To test the hypothesis, three basic choice problems were developed, involving apartments, courses and vacations. The problems involved fewer features than Sherman had used in his previous work. There were six variants of each problem, obtained by adding a feature (always positive) to one or the other of the options. The other independent variable in the study was endowment vs sequence. In the endowment condition, subjects were instructed to assume that they already had the first option, but could switch to the other without any cost or inconvenience. In the sequence condition subjects were simply presented with the problems on successive pages of a booklet, with instructions not to turn back.

The experiment was carried out in Indiana, with a total of 180 subjects (90 each in the endowment and in the sequence condition). Each subject made three choices, randomly allocated among the six possible variants described above. The statistical analysis of the data is incomplete at this writing, but the main results of the study are already in, and Sherman and I have discussed their implications, which we find interesting, and very promising. The main results are presented in Table 5.3, which shows mean ratings of preference for the various experimental conditions, collapsing over the three sets of problems. The subjects had expressed their relative preference for the two options on a 10-point scale. In Table 5.3, a high score represents a preference for the alternative to the endowed option, or for the second item presented.

Table 5.3
Effect of added positive feature on preference for alternative to endowment, or for second item

ENDOWMENT	
feature added to endowed option	-1.53
feature added to alternative	0.73
SEQUENCE	

feature added to first option	-1.36
feature added to second option	0.15

The results for the endowment condition are much as expected from the loss aversion hypothesis. Adding a positive feature to the endowed option has a large effect in making the alternative less attractive than in the corresponding control problem. Adding the same feature to the alternative option has a much smaller positive effect on the attractiveness of that option. The difference is highly significant overall. A more detailed analysis indicates that the effect is entirely due to two of the three problems: vacations and courses. There was no significant effect of the experimental manipulation of endowment on choices between apartments. With the wisdom of hindsight, this result appears quite reasonable: all respondents live somewhere, and are likely to adopt their own living circumstances as the reference for a choice between apartments. The verbal manipulation of reference state is quite weak, compared to a self-centered comparison. This hypothesis will soon be tested in a special experiment.

The more important results of Table 5.3 concern the sequence condition. Here the expected effect was that adding a positive feature to the second item in the sequence would increase its attractiveness, whereas adding a similar feature to the first would have less impact on preferences. The result is the opposite of what was expected, but it fits quite precisely the pattern anticipated for the endowment condition.

It is evident that the attempted replication of the original Houston et al study failed decisively. The tentative conclusion that Sherman and I have drawn from this failure is that the original results need not have been interpreted as an instance of Tversky's focusing hypothesis. A simple memory effect is a more likely explanation of the findings. When the options are described by a long list of features, many of which are shared, the subject will identify the shared features because they appear familiar, and the features that are unique to the second item, because they do not. The features that are unique to the first item will not be recalled and will therefore not affect the choice.

The lists of features used in the present study were much shorter than those used in the Houston et al experiments. It was therefore possible for the subjects to remember the features of the first alternative when evaluating the second. A further hypothesis must be invoked to explain the asymmetric effects of adding the positive feature to the first or to the second item in a sequence: this is simply that the first item in a sequence of options is treated as an endowment, even in the absence of specific instructions to do so. Under these conditions loss aversion will control the results, inducing a choice primacy effect, where the first items shown have an advantage. We believe that the adoption of the first item (if it is acceptable) as a reference state is also a memory effect. The hypothesis is that the sequence effect will vanish when the two items to be compared are presented on the same page, because the subject will be able to look back and forth between the options, successively adopting each as a reference for the other. This idea has obvious testable implications, which are of considerable interest for any theory of choice.

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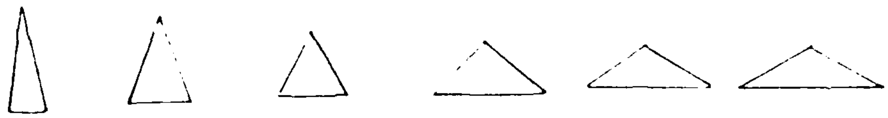

1,1	1,2	1,3	1,4	1,5	1,6	RED
2,1	2,2	2,3	2,4	2,5 CORE	2,6	FUSCHIA
3,1	3,2	3,3	3,4	3,5	3,6	VIOLET
			4,4	4,5	4,6	LILAC
			5,4	5,5	5,6	LAVENDER
			6,4	6,5	6,6	BLUE-VIOLET

Figure 2.1. Stimulus matrix for color-shape condition.

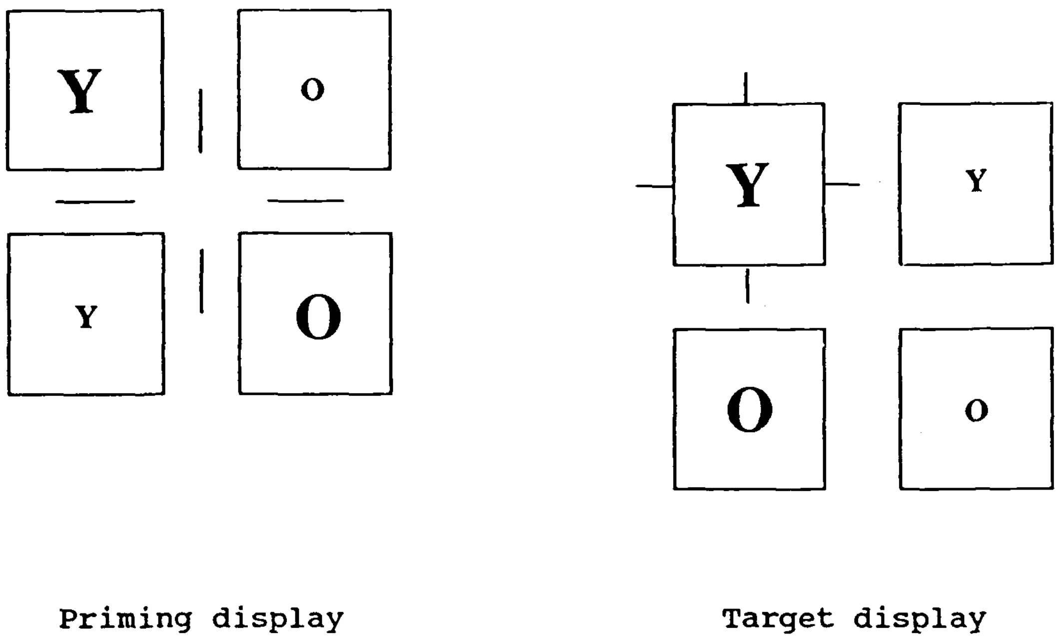

Figure 3.1: Example of display sequence. Priming display is followed by target display.